

AD\_\_\_\_\_

Award Number: W81XWH-04-2-0050

**TITLE:** NMMC Picture Archiving and Communication Systems (PACS)

**PRINCIPAL INVESTIGATOR:** Robert C. Becker, M.D.

**CONTRACTING ORGANIZATION:** North Mississippi Medical Center Inc.  
Tupelo, MS 38801-4996

**REPORT DATE:** April 2007

**TYPE OF REPORT:** Annual

**PREPARED FOR:** U.S. Army Medical Research and Materiel Command  
Fort Detrick, Maryland 21702-5012

**DISTRIBUTION STATEMENT:** Approved for Public Release;  
Distribution Unlimited

The views, opinions and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy or decision unless so designated by other documentation.

# REPORT DOCUMENTATION PAGE

Form Approved  
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing this collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.

1. REPORT DATE (DD-MM-YYYY) 01-04-2007	2. REPORT TYPE Annual	3. DATES COVERED (From - To) 29 Mar 2006 – 28 Mar 2007		
4. TITLE AND SUBTITLE  NMMC Picture Archiving and Communication Systems (PACS)		5a. CONTRACT NUMBER		
		5b. GRANT NUMBER W81XWH-04-2-0050		
		5c. PROGRAM ELEMENT NUMBER		
6. AUTHOR(S)  Robert C. Becker, M.D.  E-Mail: <a href="mailto:rbecker@nmhs.net">rbecker@nmhs.net</a>		5d. PROJECT NUMBER		
		5e. TASK NUMBER		
		5f. WORK UNIT NUMBER		
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)  North Mississippi Medical Center Inc. Tupelo, MS 38801-4996		8. PERFORMING ORGANIZATION REPORT NUMBER		
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)  U.S. Army Medical Research and Materiel Command Fort Detrick, Maryland 21702-5012		10. SPONSOR/MONITOR'S ACRONYM(S)		
		11. SPONSOR/MONITOR'S REPORT NUMBER(S)		
12. DISTRIBUTION / AVAILABILITY STATEMENT Approved for Public Release; Distribution Unlimited				
13. SUPPLEMENTARY NOTES				
14. ABSTRACT  Most deliverables for this project period were met: •PACS equipment became fully operational at 13 primary care clinics in rural Mississippi (2 clinics are scheduled to be installed and operational in June 2007) and radiology staff at all 13 sites were thoroughly trained, ▪Measurement of efficiency of radiologists and primary care providers (PCPs) compared to baseline, ▪Measurement of satisfaction of PCPs compared to baseline, ▪ Measurement of efficacy of PCPs providing the initial interpretation of radiological studies – prior to and after the implementation of PACS, ▪Plans to install revised ARSAM Systems Design Plan to address penetration issues identified during initial testing of PACS ▪Plans to perform another penetration test to assess resistance to intrusion and device compromise.				
15. SUBJECT TERMS PACS, ARSAM, clinical outcomes				
16. SECURITY CLASSIFICATION OF:  a. REPORT U		17. LIMITATION OF ABSTRACT UU	18. NUMBER OF PAGES 13	19a. NAME OF RESPONSIBLE PERSON USAMRMC
b. ABSTRACT U				19b. TELEPHONE NUMBER (Include area code)
c. THIS PAGE U				

## Table of Contents

<b>Introduction.....</b>	<b>4</b>
<b>Body.....</b>	<b>4</b>
<b>Key Research Accomplishments.....</b>	<b>5</b>
<b>Reportable Outcomes.....</b>	<b>12</b>
<b>Conclusions.....</b>	<b>12</b>
<b>References.....</b>	<b>13</b>
<b>Appendices.....</b>	<b>13</b>

## **Introduction**

The project period encompasses the third phase of a three-phase initiative to install Picture Archiving and Communication Systems (PACS) and Teleradiology at North Mississippi Medical Center's (NMMC) main hospital campus in Tupelo, four community hospitals in northeastern Mississippi, and at 15 clinics and to test relevant research hypotheses pertaining to quality, security, and clinical issues.

Phase I involved 1) installation of PACS equipment secured with Army Security Architecture for Medical (ARSAM) Systems Design Plan on all freestanding buildings on the NMMC campus, including NMMC-Tupelo, Women's Health Center, Longtown Imaging, Digestive Health, Internal Medicine Associates, and the Cancer Center, 2) training of NMMC's radiologists, and 3) design of research database.

Phase II deliverables included 1) installation of PACS equipment secured with ARSAM Systems Design Plan at four community hospitals in northeastern Mississippi, 2) training of all radiology staff members at these facilities, 3) multiple tests of security architecture, and 4) collection and analysis of efficiency, satisfaction, and outcome data.

Phase III deliverables include 1) PACS equipment became fully operational at 13 primary care clinics in rural Mississippi (2 clinics are scheduled to be installed and operational in June 2007), 2) Radiology staff at all 13 sites were thoroughly trained, 3) measurement of efficiency of radiologists and primary care providers (PCPs) compared to baseline, 4) measurement of satisfaction of PCPs compared to baseline, 5) measurement of efficacy of PCPs providing the initial interpretation of radiological studies – prior to the implementation of PACS, 6) plans to install revised ARSAM Systems Design Plan to address penetration issues identified during testing of the PACS system and, 7) plans to perform another penetration test to assess resistance to intrusion and device compromise.

## **Body**

Three years ago, NMMC, in conjunction with its health system, North Mississippi Health Services (NMHS), proposed a three-phase initiative to install Picture Archiving and Communication Systems (PACS) and Teleradiology at its main hospital campus, four community hospitals in northeastern Mississippi, one community hospital in northwestern Alabama, and at 15 clinics. In addition to improving the quality of radiology services for people living in this rural region, including military personnel, military reserve personnel, and military dependents, the PACS systems would be used to test security architecture for networked medical devices, an initiative of critical importance to the military, and to research clinical outcomes associated with PACS technology that are of significance to the military and other health care operations.

The hypotheses to be tested were that implementation of state-of-the-art PACS on the NMMC-Tupelo campus, four community hospitals, and other sites affiliated with the NMHS system

will 1) improve radiology efficiency, 2) improve clinical outcomes, and 3) demonstrate that networked PACS can be made secure to intrusion and device compromise.

Expected results of the initiative included:

- 1) Increased efficiency of radiologists as measured by performance indicators
- 2) Decreased number of radiology support staff (film librarians and technicians)
- 3) Increased satisfaction of radiologists, other medical providers, and patients as measured by satisfaction surveys (medical staff, radiologists, and consumers)
- 4) Identification of highly effective security architecture for networked PACS systems that can be replicated for Army Medicine's networked medical devices, including PACS
- 5) Improved clinical outcomes as measured by specific radiology indicators on the length of stay (LOS) and other indicators for CAP and stroke

Potential benefits of the three-phase project included:

- Demonstration of radiology service management at remote locations
- Information on the impact of PACS technology on clinical outcomes for CAP and stroke
- Demonstration of secure teleradiology services at remote locations

The project's relevance to the military is related to its capacity to:

- Simulate the military's management of radiology services in remote, noncombat settings
- Validate ARSAM security architecture for PACS
- Ensure availability of high quality radiological services for military personnel, reserve personnel, and dependents

### **Project Period Deliverables and Results**

Most deliverables for this project period were met during the period from April 28, 2006 to April 28, 2007. As noted below, 2 clinic installations are not yet complete and until installation is complete penetration testing cannot be performed.

- PACS equipment became fully operational at 13 rural primary care clinics: Pulmonary Clinic, Family Medicine Residency Center, Barnes Crossing, Med Serve, Eupora FMC, Okolona FMC, North Columbus FMC, Lowndes FMC, Pontotoc FMC, Fulton FMC, Baldwyn FMC, Oxford FMC, Chickasaw FMC (Hamilton Medical Clinic and Saltillo FMC are being implemented in June 2007)
- Radiology staff at all 13 sites were thoroughly trained.
- Measurement of efficiency of radiologists and primary care providers (PCPs) compared to baseline,
- Measurement of satisfaction of PCPs compared to baseline,
- Measurement of efficacy of PCPs providing the initial interpretation of radiological studies – prior to and after the implementation of PACS,

- Once the clinic installation is complete, the ARSAM System Design Plan network security changes will be installed,
- Network vulnerability assessment and penetration tests are being scheduled for August or September 2007 to assess resistance to intrusion and device compromise.

## Key Research Accomplishments

➤ **Research Area: Impact of PACS on efficiency of radiologists as measured by performance indicators**

Dramatic reductions were noted in Report Turnaround Time, the time that elapses following completion of the procedure and receipt of the radiologist's interpretation of the image, pre- and post-installation of PACS capabilities. We randomly selected 60 patients who received a chest x-ray at one of the clinics prior to and after the implementation of PACS. The pre-PACS timeframe was January 2006 and the post-PACS timeframe was December 2006. Prior to the implementation of PACS in the clinics, an x-ray would be performed in the clinics and then transported by courier to the radiologist in Tupelo (a distance of over 90 miles for the most remote clinic). The Tupelo-based radiologist would interpret the study and send the interpretation via the electronic medical record (EMR) that links the hospitals and clinics. A chart review of the EMR was performed and the following elements were collected to examine the efficiency of the PACS system in the clinics (see figure 1 for results):

- When the patient visit occurred (*date and time – in minutes*);
- When the radiologist's interpretation was available in the EMR;
- When the PCP's signature appeared on the radiologist's interpretation (*to indicate the PCP had seen the radiologist's interpretation*); and
- When the final primary care provider (PCP) signature appeared on the overall visit (*to indicate the PCP's closure on this episode*).

A 2-sample t-test, adjusted for unequal variance, where appropriate, was used to calculate the p-values:

**Figure 1: Pre and Post-PACS efficiency in NMHS clinic setting**

	Pre-PACS (hrs)	Post-PACS(hrs)	p-value
<b>Radiologist's interpretation available on EMR</b>	<b>49</b>	<b>1.6</b>	<b>&lt;.0001</b>
<b>PCP signs off on radiologist's interpretation in EMR</b>	<b>44</b>	<b>35</b>	<b>.2406</b>

<b>PCP final sign off on visit</b>	<b>90</b>	<b>37</b>	<b>&lt;.0001</b>
------------------------------------	-----------	-----------	------------------

It appears that the radiologists have significantly reduced the turnaround time for reporting their interpretations on patients' EMR's. The PCPs, however, have not significantly reduced the time before signing off on having read the radiologists' interpretations. The PCP's final sign off on the patient's chart, however, did reduce significantly.

➤ **Research Area: Impact of PACS on costs for film reduction and decreased courier usage.**

The North Mississippi Medical Clinics Inc. (NMMCI) administrators performed this evaluation. They noted a decrease in film costs, but an overall increase in their MIS support fees and increased bandwidth costs. These increases more than outweigh the film reduction savings and since January 2007, their radiology costs are up by 22% since the implementation of PACS. There is no decrease in courier costs, since the courier is still transporting other materials between NMMC-Tupelo and the clinics.

➤ **Research Area: Impact of PACS on satisfaction of primary care providers (clinic-based physicians and nurse practitioners).**

In June 2007, 25 PCP's in the 13 clinics that have implemented PACS returned the survey. This is a 5-point survey with the PCP rating 5 for "excellent" and 1 for "poor". Their results are compiled and compared to the baseline survey that was completed with PCP's from the entire region. Note, the original pre-PACS questions primarily referred to radiologic studies being performed at the hospitals. In each of the four categories of satisfaction questions, the cumulative score increased from the baseline survey in 2003 to post-PACS in 2007. Refer to Figure 2.

**Figure 2: Clinic-based PCP Satisfaction with PACS Survey Results**

<b>Referring Physicians/Clinic-based PCPs</b>	<b>2003</b>	<b>2007</b>
<b>Scheduling &amp; Registration</b>	<b>3.65</b>	<b>4.42</b>
<ul style="list-style-type: none"> <li>- Time it takes to schedule outpatients</li> <li>- Responsiveness for urgent patients</li> </ul>		4.40 4.44
<b>Physician Needs</b>	<b>3.74</b>	<b>4.66</b>
<ul style="list-style-type: none"> <li>- Availability of radiologists to review films</li> <li>- Timeliness of receiving preliminary reports</li> <li>- Timeliness of receiving final reports</li> <li>- Timeliness in completion of urgent exams</li> <li>- Report turn-around time for urgent patients</li> </ul>		4.76 4.60 4.72 4.76 4.64

<b>Referring Physicians/Clinic-based PCPs</b>	<b>2003</b>	<b>2007</b>
<b>Patient Needs</b>  - Waiting time in the department - Customer service attitude & tech performance	3.72	<b>4.43</b>  4.43 4.43 Oxytocin, Basic Behavioral Research, Relationships, Sexual Activity, Longitudinal, Human Subjects
<b>Radiologists</b>  - Quality & accuracy of interpretation - Availability for consultation - Calling of positive reports to physicians	3.93	<b>4.48</b>  4.74 4.64 4.08

To supplement the empirical data, which trends strongly to greater satisfaction with radiology services, PCP respondents write-in comments are presented in Figure 3:

**Figure 3: Clinic-based PCP Survey Write-in Comments (2007)**

**If you have checked off any “needs improvement” or “poor,” please tell us why**

- None noted

**Do you feel that the implementation of PACS has changed the way you treat patients? For example, if the turn around time for reports is faster, has this helped with your ability to diagnose and treat patients?**

- Yes, excellent results and service. Able to make diagnosis quicker.
- Much improved, positive improvement.
- It is very helpful when the report comes back while the patient is still here (this happens sometimes, but not always). Overall, I am very happy with the system and like it much better than hard copy films. Especially nice to be able to discuss with radiologist on phone while looking at film.
- It has been very helpful sometimes to have radiologist report in hand when discussing former radiographic abnormalities with patients.
- Not really.

**Please provide us with any comments or suggestions you have regarding imaging services.**

- At first I wasn't sure how this was going to be helpful. Now after using PACS and seeing how quick it is and how fast we get the reports back, I love it!
- Keep up the good turn around time on film review by physician.
- I have enjoyed the ability to magnify images; service has been faster for patients.
- Great service.
- Please continue.

### **Research Area: Improved clinical outcomes**

During the randomly-selected 60 patient pre- and post-PACS chart review, two more data elements were collected to examine the clinical efficacy of the PACS system in the clinics:

- If the PCP documented his/her own interpretation of the study; and
- If the PCP's and the radiologist's interpretation agreed with each other.

A chi square test was performed to determine the p-value.

**Figure 4: Clinical impact of PACS of NMHS clinic patients**

	Pre-PACS (%)	Post-PACS (%)	p-value
<b>Cases of PCPs who documented their interpretation of their patients' chest x-ray</b>	<b>28 pts (47%)</b>	<b>28 pts (47%)</b>	<b>1.00</b>
<b>Cases of agreement between PCPs interpretation and the radiologists' interpretation</b>	<b>25 pts (89%)</b>	<b>24 pts (86%)</b>	<b>1.00</b>

One of the basic premises of implementing PACS in the clinics is to provide the clinic-based PCP's with the radiologist's interpretation during the patient's visit. As noted in Figure 1, the turnaround time of the arrival of the radiologist's interpretation on the patient's EMR decreased from 49.0 to 1.6 hours. This incredible improvement, however, did not change the frequency of the PCP's recording their own interpretations on the EMR (47% pre and post PACS). And, understandably, it did not appreciably change the agreement between the PCP and radiologists (89% pre and 86% post PACS).

It is not possible to assess the actual impact on the PCP's use of the information they received. Based on their comments in the satisfaction survey (Figure 3), it appears that the physicians are using the radiologists' interpretations to make their treatment decisions.

Each of the seven cases of disagreement between the PCP's and the radiologist's interpretation of the patients' chest x-ray (CXR) was reviewed by the clinic system's quality improvement physician. He determined whether there was any clinical impact on the patient's care because of the disagreement.

Pre-PACS Cases	Case Description	Clinical Impact
1	The PCP interpreted the CXR of 52 yo male with coughing and wheezing as a “little patch of pneumonitis” and prescribed antibiotics for bronchitis. The radiologist interpreted the CXR as “within normal limits.”	None – would also treat these clinical symptoms with antibiotics
2	The PCP interpreted the CXR of 16 yo female with back pain in her left flank area as “possible costochondral tear” and treated her with a mild pain medicine and an anti-inflammatory agent. The radiologist interpreted the CXR as a “negative examination.”	None- would also treat the pt’s pain with pain med & anti-inflammatory agents
3	The PCP interpreted the CXR of 68 yo female with cough, cold and congestion “infiltrate of left lower lung” and prescribed antibiotics for bronchitis. The radiologist interpreted the CXR as “within normal limits.”	None – would also treat these clinical symptoms with antibiotics
Post-PACS Cases	Case Description	Clinical Impact
1	The PCP interpreted the CXR of 57 yo male with cough, chest congestion and wheezing as “chronic changes and light bronchial cuffing” and prescribed antibiotics and an inhaler for bronchitis. The radiologist interpreted the CXR as “unremarkable chest.”	None – would also treat these clinical symptoms with antibiotics and an inhaler
2	The PCP interpreted the CXR of 6 yo female who is on a return visit for her bad cough as “a suspicious area in the left base for an infiltrate” and prescribed a different antibiotic and a corticosteroid for possible pneumonia. The radiologist interpreted the CXR as “and infiltrate in the lingular segment of the left upper lobe ... felt to represent a left upper lobe pneumonitis.”	None- it is difficult to make fine anatomical distinctions in a small child. The interpretations were similar and the treatment would be the same.
3	The PCP interpreted the CXR of 70 yo female with lung congestion as “no consolidations, infiltrates or effusions” and prescribed antibiotics and cough medicine for bronchitis. The radiologist interpreted the CXR as “a slight increase in the size of the vague nodular opacity in the right upper lobe.”	Possible – would require a CT of the chest to examine nodular opacity. <i>Follow-up: PCP ordered the chest CT the following day.</i>
4	The PCP interpreted the CXR of 9 yo female with nighttime cough and shortness of breath as “clear” and prescribed	None – different terminology but

	antibiotics, cough medicine and a corticosteroid for bronchitis. The radiologist interpreted the CXR as “peribronchial wall change consistent with bronchitis.”	same diagnosis and treatment.
--	---	-------------------------------

From this relatively small sample, it does not appear that PACS has made any difference in the clinic patients' clinical outcomes.

While PACS increased the speed with which the radiologists' returned their interpretations, it did not demonstrate an impact on clinical outcomes in the current study. In retrospect, we may have assessed the impact too soon after implementation to see any difference in PCP behavior. Although PCP's indicated they are looking at the radiologists' studies before making their decisions (per satisfaction comments), they did not appear to sign off on the radiologists' notes significantly earlier than before. This may indicate that many of the PCP's have not yet incorporated this new technology into their practices. We may want to reassess the clinics after they have had more than 1-2 months of experience using PACS.

### **Project Period Security Architecture Testing**

- **Research Area: Identification of highly effective security architecture for networked PACS systems that can be replicated for Army Medicine's networked medical devices, including PACS**

*BACKGROUND regarding phase-2 evaluation: NMMC contracted Sword & Shield Enterprise Security, Inc. (Sword & Shield) to conduct a network vulnerability assessment and penetration test of NMMC's external and internal networks. The assessment examined NMMC's implementation of the Army Security Architecture for Medical (ARSAM), a defense-in-depth network security architecture for FDA-approved medical devices. NMMC is using ARSAM in its deployment of the PACS within its hospital information system network.*

*Sword and Shield Findings from May 2006:*

- *From an external perspective, the overall security posture of the NMMC network was deemed to be satisfactory. The firewall and network devices provided an adequate level of protection to the NMMC internal network, and PACS network, from Internet-based threats.*
- *However, Sword and Shield was able to circumvent the ARSAM protections implemented at NMMC during the internal phase of testing by taking advantage of some PACS devices that were located outside of the protected enclave and also by taking advantage of other devices on the network which were not patched with all of the latest security patches or system/applications updates.*

**CURRENT STATUS:** The recommended security patches have been installed into the PACS system. Once the PACS systems are installed at the final two clinics, NMHS will contact Sword and Shield to request that they conduct a second network vulnerability assessment and penetration test of NMMC's external and internal networks.

### **Reportable Outcomes**

To date, no manuscripts, abstracts, grant applications, patents, etc. have been submitted that are direct results of this project.

## **Conclusions**

Implementation of PACS technology on NMMC's campus in Tupelo, four community hospitals and 13 clinics has yielded information of potential value to other health care agencies serving rural regions:

### **Current (Phase-3) Report**

1. PACS technology is associated with dramatic decreases in radiological report turn-around in rural clinic settings.
2. Clinic-based PCP's reported greater satisfaction with radiological services following introduction of PACS capabilities.
3. The implementation of PACS did not affect the frequency of PCP's interpreting their patients' CXR's.
4. The cost of PACS appears to be higher for the clinic system.
5. The implementation of PACS did not affect the interpretation of the CRX's or the clinical treatment the patients received.

### **Previous (Phase-2) Report**

1. *PACS technology is associated with dramatic decreases in radiological report turn-around in rural hospital settings.*
2. *At two of the four community hospital sites (50 percent), the introduction of PACS technology resulted in cost savings (personnel and film)*
3. *Referring physicians reported greater satisfaction with radiological services following introduction of PACS capabilities.*
4. *Data analyzed to date does not support the hypothesis that the use of PACS technology increases the speed with which antibiotics are administered as indicated for CAP.*
5. *The low usage of tPA in the management of ischemic stroke makes it an unreliable process indicator for efficacy of PACS in the management of stroke.*
6. *Overall outcomes (length of stay, patient mortality and median cost) trended towards improvement in the post-PACS period for both CAP and stroke.*
7. *Network sensitivity and penetration testing revealed that ARSAM protections implemented at NMMC were inadequate and that additional precautions needed to be taken in the security system architecture.*

As required by the Research Technical Reporting Requirements, "So what?" Work completed during the three phases of PACS implementation and research at NMMC does indeed have implications for rural hospitals/health systems and for the military. PACS technology has dramatically increased the turn-around time for radiological images and increased significantly the number of "first reads" made by radiologists rather than other physician specialists. PACS technology will likely be instrumental in improving physician satisfaction with radiological services

at other rural clinics and hospitals, which struggle to recruit and retain qualified health care providers. When contemplating implementation of PACS, some hospitals may be able to project cost savings from personnel or supply (film) budgets, however, our Phase-3 clinic-based study actually showed an increase in costs due to additional IS support costs over film savings.

The results of network sensitivity and penetration testing completed to date at NMMC suggest that ARSAM protections must be enhanced to guard patient data, which will guide other rural hospitals in the implementation and design of their PACS systems. Test results are also of significance to the military's efforts to deliver radiological services from remote, noncombat sites to battlespaces.

The health system's experiences will be used to formulate recommendations for installation, implementation, and application of PACS systems, including highly effective security architecture. Data collected on indicators pertinent to clinical outcomes will be used to document the impact of PACS technology in civilian applications.

## **References**

Andriole KP. Productivity and Cost Assessment of Computed Radiography, Digital Radiography, and Screen-Film for Outpatient Chest Examinations. *J Digital Imaging*. 2002; 15(3); 161-169.

Andriole KP, Luth DM, Gould RG. Workflow Assessment of Digital versus Computed Radiography and Screen-Film in the Outpatient Environment. *J Digital Imaging*. 2002; 15(Suppl1); 124-126.

Hangiandreou NJ, King BR, Swenson AR, et al. Picture Archive and Communication Systems Implementation in a Community Medical Practice. *J Digital Imaging*. 1997; 10(3),Suppl 1; 36-37.

Patel MD, Callen PW, Mar JB, et al. Evaluation of a Sonographic PACS in Clinical Practice: Analysis of Technical and Analytical Time Savings. *Ultrasound Med*. 1996 15: 755-762.

## **Appendices**

*Not applicable*